Predicting smoke layer temperatures in multi-room compartments

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INTRODUCTION

Two-zone and CFD models can be used to calculate smoke layer heights, species and temperatures etc. in multi-room compartments. These types of fire models are generally good tools for fire engineering purposes. However, there is still a need for simple engineering methods, because simple hand-calculations methods can be used for to get an estimate or indication before any more advanced and time consuming analysis are conducted.

In this poster two recently developed hand-calculation methods to predict smoke layer temperatures in a room adjacent to the room of fire origin are presented and compared to results from CFAST simulations.

THE METHODS

The first method (Method 1) has been developed in order to predict room temperatures in a room adjacent to the room of fire origin. The method is based on a numerical experiment that included 100 FDS simulations with different room configurations and heat release rates. Method 1 includes the following correlation that has been determined with a multiple regression analysis of the data from the numerical experiment.

$$\Delta T_2 = 10.4 \frac{\dot{Q}^{0.73} VF_{1-2}^{0.24}}{A_{T,1}^{0.45} A_{T,2}^{0.33} VF_{2-out}^{0.19} h_k^{0.34}} \qquad (1)$$

Q is the heat release rate, VF_{1-2} is the ventilation factor between the first and second room and $VF_{2\text{-out}}$ is the ventilation factor between the second room and the outside. A_T represents the total surface area in each room and h_k is the heat transfer coefficient. More information about this method can be found in [1].

A simple energy balance for a two-room configuration is used in the second method (Method 2). The energy balance can be applied when the only opening from the fire room is to the adjacent room and the adjacent room has an opening to the outside. The energy balance is as follows:

$$\dot{Q} = \dot{m}_{g,2-out}\, c_p \left(T_{g,2} - T_a\right) + \dot{q}_{loss1} + \dot{q}_{loss2} \qquad (2)$$

Q is the heat release rate. The first term on the right-hand side describes the convective energy flux flowing out through an opening in the adjacent room, and the second and third term describes the heat loss to boundaries in the fire room and the adjacent room respectively.

The procedure to solve the heat balance in equation 2 is described in the following four points:

1. Calculate the height to the smoke layer z, by assuming m_p=m_g and by using the following two relationships:

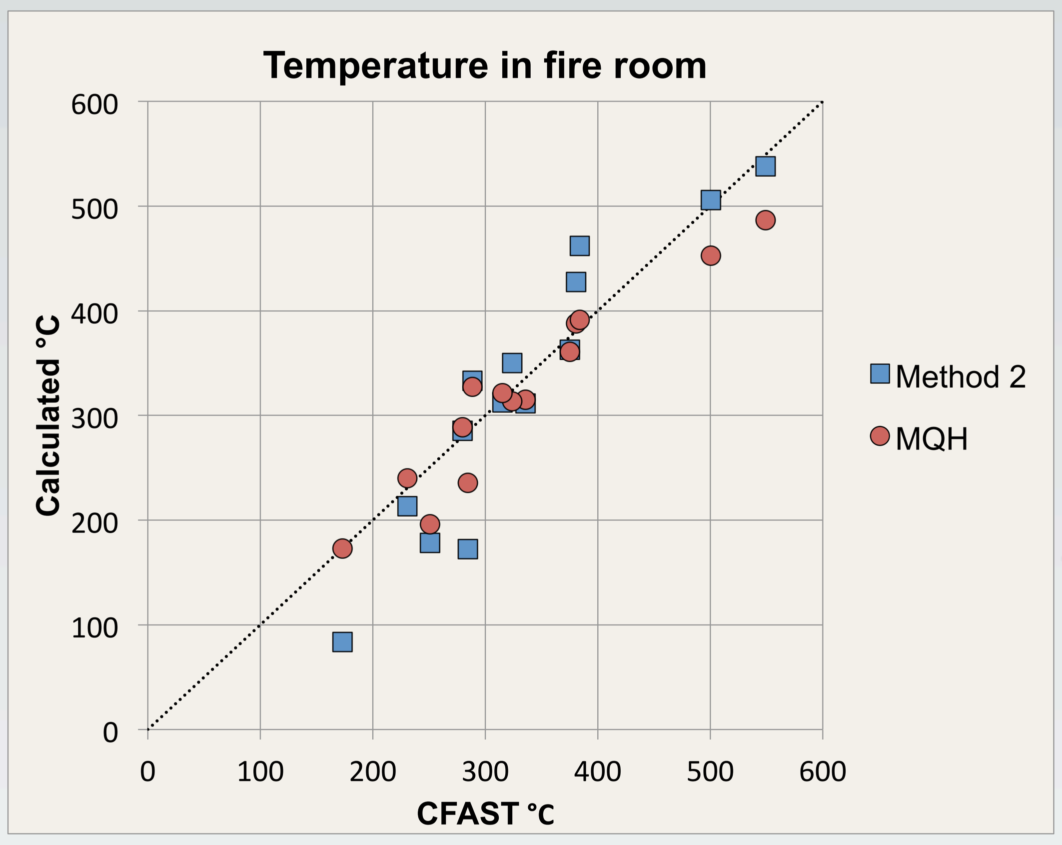
$$\dot{m}_g = 0.68 A_0 H_0^{1/2}\left(1 - z / H_0\right) \qquad (3)$$

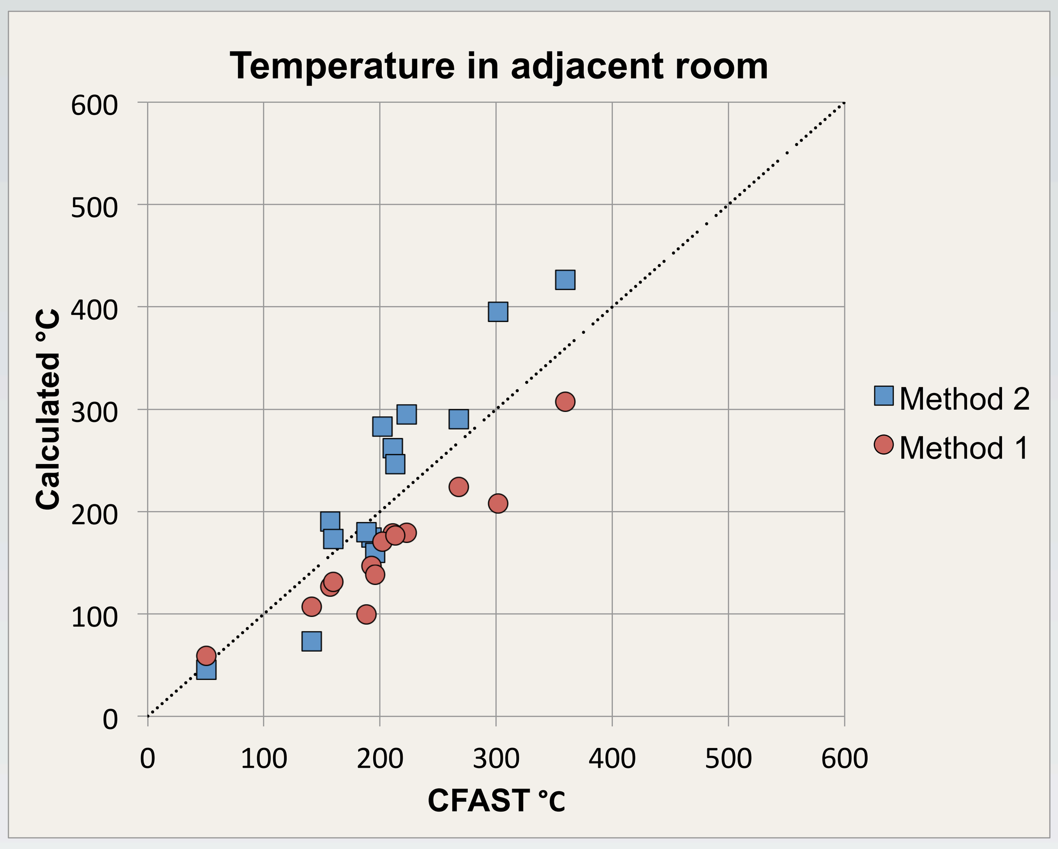
$$\dot{m}_p = 0.0056 \dot{Q}_c \,(z / L) \qquad (4)$$

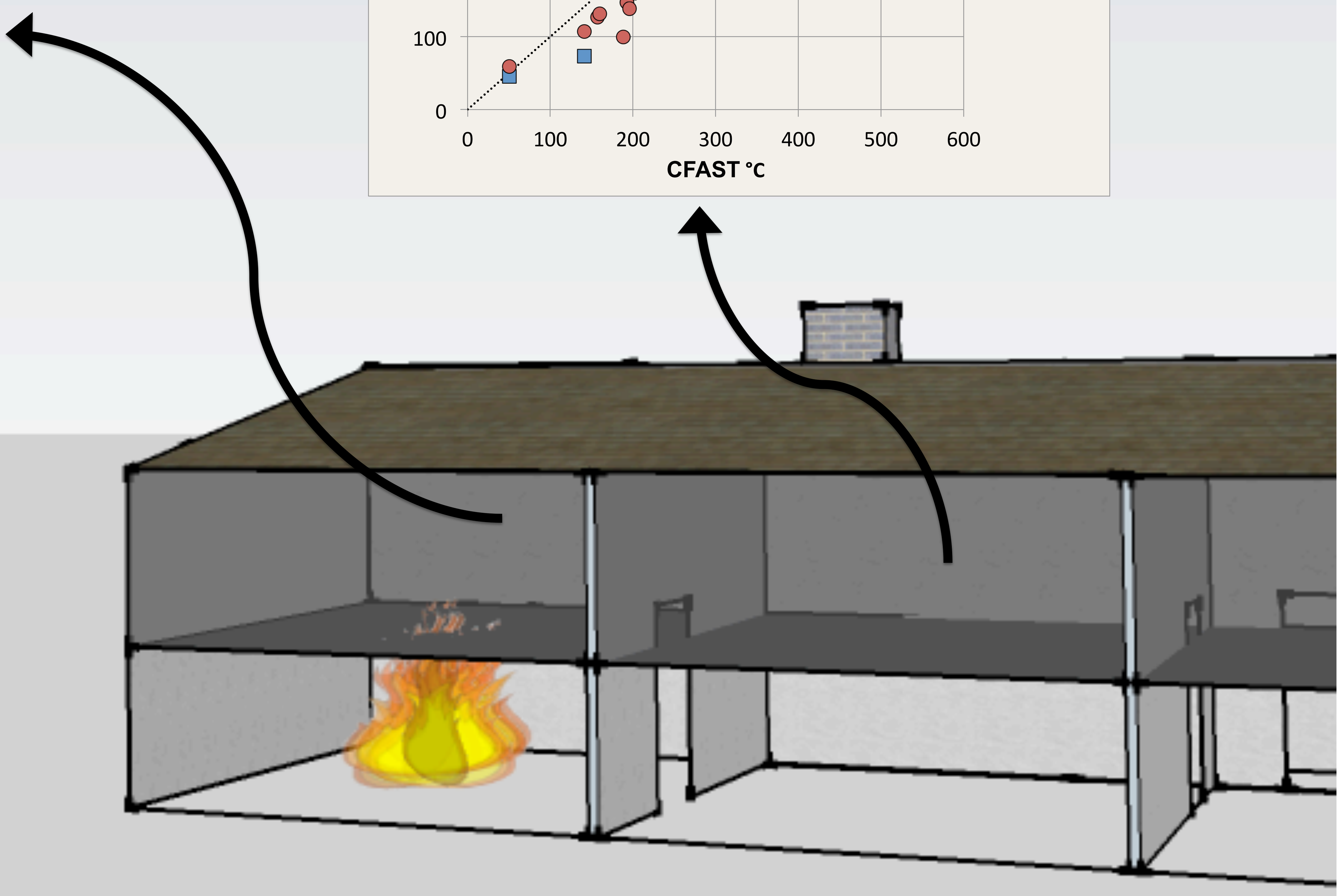
Equation 3 is based on work by Johansson & van Hees [2] and equation 4 by Heskestad [3].

2. Calculate m_g with equation 3.
3. Calculate: $\Delta T_1 = \dot{Q} / (\dot{m}_g c_p + hA_{T,1})$
4. Calculate: $\Delta T_2 = \dot{m}_g c_p \Delta T_1 / (\dot{m}_g c_p + hA_{T,2})$

The two methods are compared to 13 calculations with CFAST for different room configurations and heat release rates in the graphs below. In the first room the smoke layer temperature is estimated with method 2 (according to step 3 above) and the well-established MQH method [4]. In the second room the temperature is calculated with equation 1 and step 4 above. The main cause for the disagreement between the methods is due to the uncertainty in the estimation of the heat transfer coefficient.







ADVANTAGES AND DISADVANTAGES

The first method has the advantage of being a single and rather simple correlation. On the other hand it is a black box method based on a fit to data from numerical experiments. The second method is more transparent and flexible and will not only give the temperature in the adjacent room but also the hot layer height and temperature in the fire room. A disadvantage of the second method is that it demands several separate calculations.

Both methods require knowledge about the heat losses to the boundaries which can be difficult to determine.

REFERENCES

1. N. Johansson, P. van Hees, A correlation for predicting smoke layer temperature in a room adjacent to a room involved in a pre-flashover fire, Fire and Materials. 2012. DOI: 10.1002/fam.2172
2. N. Johansson, P. van Hees, A Simplified Relation Between Hot Layer Height and Opening Mass Flow, in: 11th International Symposium on Fire Safety Science, Christchurch, New Zeeland, 2014.
3. Karlsson, B. & Quintiere, J.G., Enclosure Fire Dynamics, CRC Press, 1999.
4. McCaffrey, B.J., Quintiere, J.G. and Harkleroad, M.F., Estimating Room Temperatures and the Likelihood of Flashover Using Fire Test Data Correlations, Fire Technology, Vol. 17, No. 2, 1981, pp. 98–119.